The GNU Shepherd Manual

For use with the GNU Shepherd 0.10.5
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1 Introduction

This manual documents the GNU Daemon Shepherd, or GNU Shepherd for short. The Shepherd looks after system services, typically *daemons*. It is used to start and stop them in a reliable fashion. For instance, it will dynamically determine and start any other services that our desired service depends upon.

The Shepherd is the *init system* of the GNU operating system—it is the first user process that gets started, typically with PID 1, and runs as `root`. Normally the purpose of init systems is to manage all system-wide services, but the Shepherd can also be a useful tool assisting unprivileged users in the management of their own daemons.

Flexible software requires some time to master and the Shepherd is no different. But don't worry: this manual should allow you to get started quickly. Its first chapter is designed as a practical introduction to the Shepherd and should be all you need for everyday use (see Chapter 2 [Jump Start], page 2). In chapter two we will describe the `herd` and `shepherd` programs, and their relationship, in more detail (Chapter 3 [herd and shepherd], page 5). Subsequent chapters provide a full reference manual and plenty of examples, covering all of Shepherd's capabilities. Finally, the last chapter provides information for those souls brave enough to hack the Shepherd itself.

The Shepherd was formerly known as "dmd", which stands for *Daemon Managing Daemons* (or *Daemons-Managing Daemon*?).

This program is written in Guile Scheme. Guile is also the Shepherd's configuration language. See Section "Introduction" in *GNU Guile Reference Manual*, for an introduction to Guile. We have tried to make the Shepherd's basic features as accessible as possible—you should be able to use these even if you do not know how to program in Scheme. A basic grasp of Guile is required only if you wish to make use of the Shepherd's more advanced features.

2 Jump Start

This chapter gives a short overview of the Shepherd. It is enough if you just need the basic features of it. As it is not assumed that readers are familiar with all the involved issues, a very experienced user might be annoyed by the often very detailed descriptions in this introduction. Those users are encouraged to just skip to the reference section.

Note that all the full file names in the following text are based on the assumption that you have installed the Shepherd with an empty prefix. If your Shepherd installation for example resides in `/usr/local` instead, add this directory name in front of the absolute file names mentioned below.

When `shepherd` gets started, it reads and evaluates a configuration file. When it is started with superuser privileges, it tries to use `/etc/shepherd.scm`. When started as normal user, it looks for a file called `$XDG_CONFIG_HOME/shepherd/init.scm`. If the `XDG_CONFIG_HOME` environment variable is not defined, `$HOME/.config/shepherd/init.scm` is used instead (see ⟨undefined⟩ [Managing User Services], page ⟨undefined⟩). With the option `--config` (or, for short, `-c`), you can specify where to look instead. So if you want to start `shepherd` with an alternative file, use one of the following commands:

```
shepherd --config=/etc/shepherd.scm.old
shepherd -c /etc/shepherd.scm.old
```

As the final "d" suggests, `shepherd` is just a daemon that (usually) runs in the background, so you will not interact with it directly. After it is started, `shepherd` will listen on a socket special file, usually `/var/run/shepherd/socket`, for further commands. You use the tool *herd* to send these commands to `shepherd`. Usage of herd is simple and straightforward: To start a service called `apache`, you use:

```
herd start apache
```

When you do this, all its dependencies will get resolved. For example, a webserver is quite likely to depend on working networking, thus it will depend on a service called `networking`. So if you want to start `apache`, and `networking` is not yet running, it will automatically be started as well. The current status of all the services defined in the configuration file can be queried like this:

```
herd status
```

Or, to get additional details about each service, run:

```
herd detailed-status
```

In this example, this would show the `networking` and `apache` services as started. If you just want to know the status of the `apache` service, run:

```
herd status apache
```

You may also view a log of service events, including the time at which each service was started or stopped, by running:

```
herd log
```

Services and their dependencies form a *graph*, which you can view, for instance with the help of xdot (`https://github.com/jrfonseca/xdot.py`), by running:

```
herd graph | xdot -
```

You can stop a service and all the services that depend on it will be stopped. Using the example above, if you stop `networking`, the service `apache` will be stopped as well—which

makes perfect sense, as it cannot work without the network being up. To actually stop a service, you use the following, probably not very surprising, command:

```
herd stop networking
```

There are two more actions you can perform on every service: the actions `enable` and `disable` are used to prevent and allow starting of the particular service. If a service is intended to be restarted whenever it terminates (how this can be done will not be covered in this introduction), but it is respawning too often in a short period of time (by default 5 times in 5 seconds), it will automatically be disabled. After you have fixed the problem that caused it from being respawned too fast, you can start it again with the commands:

```
herd enable foo
herd start foo
```

But there is far more you can do than just that. Services can not only simply depend on other services, they can also depend on *virtual* services. A virtual service is a service that is provided by one or more services additionally. For instance, a service called `exim` might provide the virtual service `mailer-daemon`. That could as well be provided by a service called `smail`, as both are mailer-daemons. If a service needs any mailer-daemon, no matter which one, it can just depend on `mailer-daemon`, and one of those who provide it gets started (if none is running yet) when resolving dependencies. The nice thing is that, if trying to start one of them fails, `shepherd` will go on and try to start the next one, so you can also use virtual services for specifying *fallbacks*.

Additionally to all that, you can perform service-specific actions. Coming back to our original example, `apache` is able to reload its modules, therefore the action `reload-modules` might be available:

```
herd reload-modules apache
```

Service-specific actions can only be used when the service is started, i.e. the only thing you can do to a stopped service is starting it. An exception exists, see below.

There are two actions which are special, because even if services can implement them on their own, a default implementation is provided by `shepherd` (another reason why they are special is that the default implementations can be called even when the service is not running; this inconsistency is just to make it more intuitive to get information about the status of a service, see below).

These actions are `restart` and `status`. The default implementation of `restart` calls `stop` and `start` on the affected service, taking care to also restart any dependent services. The default implementation of `status` displays some general information about the service, like what it provides, and what it depends on.

A special service is `root`, which is used for controlling the Shepherd itself. You can also reference to this service as `shepherd`. It implements various actions. For example, the `status` action displays which services are started and which ones are stopped, whereas `detailed-status` has the effect of applying the default implementation of `status` to all services one after another. The `load` action is unusual insofar as it shows a feature that is actually available to all services, but which we have not seen yet: It takes an additional argument. You can use `load` to load arbitrary code into the Shepherd at runtime, like this:

```
herd load shepherd ~/additional-services.scm
```

In the same vein the special action `doc` describes its service when called without an argument or describes a service-specific action when called with the action as the additional

arguments. You can even get the list of the service-specific actions a service provides when using with the additional argument `list-actions`.

```
$ herd doc root
The root service is used to operate on shepherd itself.
$ herd doc root list-actions
root (help status halt power-off load eval unload reload daemonize cd restart)
$ herd doc root action power-off
power-off: Halt the system and turn it off.
```

This is enough now about the `herd` and `shepherd` programs, we will now take a look at how to configure the Shepherd. In the configuration file, we need mainly the definition of services. We can also do various other things there, like starting a few services already.

FIXME: Finish. For now, look at the `doc/examples/` subdirectory.

...

Ok, to summarize:

- `shepherd` is a daemon, `herd` the program that controls it.
- You can start, stop, restart, enable and disable every service, as well as display its status.
- You can perform additional service-specific actions, which you can also list.
- Actions can have arguments.
- You can display the status of a service, even if the service does not provide a specific implementation for this action. The same is true for restarting.
- The `root/shepherd` service is used to control `shepherd` itself.

3 `herd` and `shepherd`

The daemon that runs in the background and is responsible for controlling the services is `shepherd`, while the user interface tool is called `herd`: it's the command that allows you to actually *herd* your daemons[1]. To perform an action, like stopping a service or calling an action of a service, you use the herd program. It will communicate with shepherd over a Unix Domain Socket.

Thus, you start `shepherd` once, and then always use herd whenever you want to do something service-related. Since herd passes its current working directory to `shepherd`, you can pass relative file names without trouble. Both `shepherd` and herd understand the standard arguments `--help`, `--version` and `--usage`.

3.1 Invoking `shepherd`

The `shepherd` program has the following synopsis:

```
shepherd [option...]
```

It accepts the following options:

'`-c file`'
'`--config=file`'

Read and evaluate *file* as the configuration script on startup.

Scheme code in *file* is evaluated in the context of a fresh module where bindings from the `(shepherd service)` module are available, in addition to the default set of Guile bindings. It may typically perform three actions:

1. defining services using the `service` procedure (see Section 4.1 [Defining Services], page 8);
2. registering those services with `register-services` (see Section 4.2 [Service Registry], page 12);
3. starting some or all of those services with `start-in-the-background` (see Section 4.3 [Interacting with Services], page 12).

See Section 4.7 [Service Examples], page 20, for examples of what *file* might look like.

Note that *file* is evaluated *asynchronously*: `shepherd` may start listening for client connections (with the `herd` command) before *file* has been fully loaded. Errors in *file* such as service startup failures or uncaught exceptions do *not* cause `shepherd` to stop. Instead the error is reported, leaving users the opportunity to inspect service state and, for example, to load an updated config file with:

```
herd load root file
```

'`-I`'
'`--insecure`'

Do not check if the directory where the socket—our communication rendez-vous with `herd`—is located has permissions `700`. If this option is not specified, `shepherd` will abort if the permissions are not as expected.

[1] In the past, when the GNU Shepherd was known as GNU dmd, the `herd` command was called `deco`, for *DaEmon COntroller*.

'`-l [file]`'
'`--logfile[=file]`'
: Log output into *file*.

  For unprivileged users, the default log file is `$XDG_STATE_HOME/shepherd/shepherd.log` with `$XDG_STATE_HOME` defaulting to `$HOME/.local/state`.

  When running as root, the default behavior is to connect to `/dev/log`, the *syslog* socket (see Section "Overview of Syslog" in *The GNU C Library Reference Manual*). A syslog daemon, `syslogd`, is expected to read messages from there (see Section "syslogd invocation" in *GNU Inetutils*).

  When `/dev/log` is unavailable, for instance because `syslogd` is not running, as is the case during system startup and shutdown, `shepherd` falls back to the Linux kernel *ring buffer*, `/dev/kmsg`. If `/dev/kmsg` is missing, as is the case on other operating systems, it falls back to `/dev/console`.

'`--pid[=file]`'
: When `shepherd` is ready to accept connections, write its PID to *file* or to the standard output if *file* is omitted.

'`-s file`'
'`--socket=file`'
: Receive further commands on the socket special file *file*. If this option is not specified, *`localstatedir`*`/run/shepherd/socket` is taken when running as `root`; when running as an unprivileged user, `shepherd` listens to `/run/user/`*uid*`/shepherd/socket`, where *uid* is the user's numerical ID[2], or to `$XDG_RUNTIME_DIR/shepherd` when the `XDG_RUNTIME_DIR` environment variable is defined.

  If `-` is specified as file name, commands will be read from standard input, one per line, as would be passed on a `herd` command line (see Section 3.2 [Invoking herd], page 6).

'`--quiet`' Synonym for `--silent`.

3.2 Invoking `herd`

The `herd` command is a generic client program to control a running instance of `shepherd` (see Section 3.1 [Invoking shepherd], page 5). When running as root, it communicates with the *system instance*—the process with PID 1; when running as a normal user, it communicates with the *user's instance*, which is a regular, unprivileged process managing the user's own services. For example, the following command displays the status of all the *system services*:

```
sudo herd status
```

Conversely, the command below displays the status of *user services*, assuming a user `shepherd` is running:

```
herd status
```

[2] On GNU/Linux, the `/run/user/`*uid* directory is typically created by elogind or by systemd, which are available in most distributions.

The command has the following synopsis:

```
herd [option...] action [service [arg...]]
```

It causes the *action* of the *service* to be invoked. When *service* is omitted and *action* is `status` or `detailed-status`, the `root` service is used[3] (see Section 4.5 [The root Service], page 18, for more information on the `root` service.)

For each action, you should pass the appropriate *arg*s. Actions that are available for every service are `start`, `stop`, `restart`, `status`, `enable`, `disable`, and `doc`.

If you pass a file name as an *arg*, it will be passed as-is to the Shepherd, thus if it is not an absolute name, it is local to the current working directory of `shepherd`, not to herd.

The `herd` command understands the following option:

'`-s` *file*'
'`--socket=`*file*'
: Send commands to the socket special file *file*. If this option is not specified, *localstatedir*`/run/shepherd/socket` is taken.

The `herd` command returns zero on success, and a non-zero exit code on failure. In particular, it returns a non-zero exit code when *action* or *service* does not exist and when the given action failed.

3.3 Invoking `reboot`

The `reboot` command is a convenience client program to instruct the Shepherd (when used as an init system) to stop all running services and reboot the system. It has the following synopsis:

```
reboot [option...]
```

It is equivalent to running `herd stop shepherd`. The `reboot` command understands the following option:

'`-s` *file*'
'`--socket=`*file*'
: Send commands to the socket special file *file*. If this option is not specified, *localstatedir*`/run/shepherd/socket` is taken.

3.4 Invoking `halt`

The `halt` command is a convenience client program to instruct the Shepherd (when used as an init system) to stop all running services and turn off the system. It has the following synopsis:

```
halt [option...]
```

It is equivalent to running `herd power-off shepherd`. As usual, the `halt` command understands the following option:

'`-s` *file*'
'`--socket=`*file*'
: Send commands to the socket special file *file*. If this option is not specified, *localstatedir*`/run/shepherd/socket` is taken.

[3] This shorthand does not work for other actions such as `stop`, because inadvertently typing `herd stop` would stop all the services, which could be pretty annoying.

4 Services

The *service* is obviously a very important concept of the Shepherd. On the Guile level, a service is represented as a record of type `<service>`. Each service has a number of properties that you specify when you create it: how to start it, how to stop it, whether to respawn it when it stops prematurely, and so on. At run time, each service has associated *state*: whether it is running or stopped, what PID or other value is associated with it, and so on.

This section explains how to define services and how to query their configuration and state using the Shepherd's programming interfaces.

> **Note:** The programming interface defined in this section may only be used within a `shepherd` process. Examples where you may use it include:
>
> - the `shepherd` configuration file (see Section 4.7 [Service Examples], page 20);
> - as an argument to `herd eval root ...` (see Section 4.5 [The root Service], page 18);
> - at the REPL (see Section 5.2 [REPL Service], page 23).
>
> These procedures may not be used in Guile processes other than `shepherd` itself.

4.1 Defining Services

A service is created by calling the `service` procedure, from the `(shepherd service)` module (automatically visible from your configuration file), as in this example:

```
(service
  '(sshd ssh-daemon)  ;for convenience, give it two names
  #:start (make-forkexec-constructor
           '("/usr/sbin/sshd" "-D")
           #:pid-file "/etc/ssh/sshd.pid")
  #:stop (make-kill-destructor)
  #:respawn? #t)
```

The example above creates a service with two names, `sshd` and `ssh-daemon`. It is started by invoking `/usr/sbin/sshd`, and it is considered up and running as soon as its PID file `/etc/ssh/sshd.pid` is available. It is stopped by terminating the `sshd` process. Finally, should `sshd` terminate prematurely, it is automatically respawned. We will look at `#:start` and `#:stop` later (see Section 4.4 [Service De- and Constructors], page 14), but first, here is the reference of the `service` procedure and its optional keyword arguments.

`service` *provision* [*#:requirement '()*] [*#:one-shot? #f*] [*#:transient? #f*] [*#:respawn? #f*] [*#:start* (*const #t*)] [*#:stop* (*const #f*)] [*#:actions* (*actions*)] [*#:termination-handler default-service-termination-handler*] [*#:documentation #f*] [Procedure]

Return a new service with the given *provision*, a list of symbols denoting what the service provides. The first symbol in the list is the *canonical name* of the service, thus it must be unique.

The meaning of keyword arguments is as follows:

`#:requirement`
: `#:requirement` is, like *provision*, a list of symbols that specify services. In this case, they name what this service depends on: before the service can be started, services that provide those symbols must be started.

  Note that every name listed in `#:requirement` must be registered so it can be resolved (see Section 4.2 [Service Registry], page 12).

`#:respawn?`
: Specify whether the service should be respawned by `shepherd`. If this slot has the value `#t`, then, assuming the service has an associated process (its "running value" is a PID), restart the service if that process terminates.

  There is a limit to avoid endless respawning: when the service gets respawned "too fast", it is *disabled*—see `#:respawn-limit` below.

`#:respawn-delay`
: Specify the delay before a service is respawned, in seconds (including a fraction), for services marked with `#:respawn? #t`. Its default value is `(default-respawn-delay)` (see Section 4.4 [Service De- and Constructors], page 14).

`#:respawn-limit`
: Specify the limit that prevents `shepherd` from respawning too quickly the service marked with `#:respawn? #t`. Its default value is `(default-respawn-limit)` (see Section 4.4 [Service De- and Constructors], page 14).

  The limit is expressed as a pair of integers: the first integer, *n*, specifies a number of consecutive respawns and the second integer, *t*, specifies a number of seconds. If the service gets respawned more than *n* times over a period of *t* seconds, it is automatically *disabled* (see Section 4.3 [Interacting with Services], page 12). Once it is disabled, the service must be explicitly re-enabled using `herd enable` *`service`* before it can be started again.

  Consider the service below:

```
(service '(xyz)
         #:start (make-forkexec-constructor ...)
         #:stop (make-kill-destructor)
         #:respawn? #t
         #:respawn-limit '(3 . 5))
```

  The effect is that this service will be respawned at most 3 times over a period of 5 seconds; if its associated process terminates a fourth time during that period, the service will be marked as disabled.

`#:one-shot?`
: Whether the service is a *one-shot service*. A one-shot service is a service that, as soon as it has been successfully started, is marked as "stopped." Other services can nonetheless require one-shot services. One-shot ser-

vices are useful to trigger an action before other services are started, such as a cleanup or an initialization action.

As for other services, the `start` method of a one-shot service must return a truth value to indicate success, and false to indicate failure.

`#:transient?`
: Whether the service is a *transient service*. A transient service is automatically unregistered when it terminates, be it because its `stop` method is called or because its associated process terminates.

  This is useful in the uncommon case of synthesized services that may not be restarted once they have completed.

`#:start`
: Specify the *constructor* of the service, which will be called to start the service. This must be a procedure that accepts any number of arguments; those arguments will be those supplied by the user, for instance by passing them to `herd start`. If the starting attempt failed, it must return `#f` or throw an exception; otherwise, the return value is stored as the *running value* of the service.

  > **Note:** Constructors must terminate, successfully or not, in a timely fashion, typically less than a minute. Failing to do that, the service would remain in "starting" state and users would be unable to stop it.

  See Section 4.4 [Service De- and Constructors], page 14, for info on common service constructors.

`#:stop`
: This is the service *destructor*: a procedure of one or more arguments that should stop the service. It is called whenever the user explicitly stops the service; its first argument is the running value of the service, subsequent arguments are user-supplied. Its return value will again be stored as the running value, so it should return `#f` if it is now possible again to start the service at a later point.

  > **Note:** Destructors must also terminate in a timely fashion, typically less than a minute. Failing to do that, the service would remain in "stopping" state and users would be unable to stop it.

  See Section 4.4 [Service De- and Constructors], page 14, for info on common service destructors.

`#:termination-handler`
: The procedure to call when the process associated with the service terminates. It is passed the service, the PID of the terminating process, and its exit status, an integer as returned by `waitpid` (see Section "Processes" in *GNU Guile Reference Manual*).

  The default handler is the `default-service-termination-handler` procedure, which respawns the service if applicable.

`#:actions`
: The additional actions that can be performed on the service when it is running. A typical example for this is the `restart` action. The `actions` macro can be used to defined actions (see below).

A special service that every other service implicitly depends on is the `root` (also known as `shepherd`) service. See Section 4.5 [The root Service], page 18, for more information.

Services and their dependencies form a *graph*. At the command-line, you can view that export a representation of that graph that can be consumed by any application that understands the Graphviz format, such as xdot (`https://github.com/jrfonseca/xdot.py`):

```
herd graph | xdot -
```

Service actions are defined using the `actions` macro, as shown below.

`actions` (*name proc*) ... [Macro]
: Create a value for the `#:actions` parameter of `service`. Each *name* is a symbol and each *proc* the corresponding procedure that will be called to perform the action. A *proc* has one argument, which will be the running value of the service.

Naturally, the `(shepherd service)` provides procedures to access this information for a given service object:

`service-provision` *service* [Procedure]
: Return the symbols provided by *service*.

`service-canonical-name` *service* [Procedure]
: Return the *canonical name* of *service*, which is the first element of the list returned by `service-provision`.

`service-requirement` *service* [Procedure]
: Return the list of services required by *service* as a list of symbols.

`one-shot-service?` *service* [Procedure]
`transient-service?` *service* [Procedure]
: Return true if *service* is a one-shot/transient service.

`respawn-service?` *service* [Procedure]
: Return true if *service* is meant to be respawned if its associated process terminates prematurely.

`service-respawn-delay` *service* [Procedure]
: Return the respawn delay of *service*, in seconds (an integer or a fraction or inexact number). See `#:respawn-delay` above.

`service-respawn-limit` *service* [Procedure]
: Return the respawn limit of *service*, expressed as a pair—see `#:respawn-limit` above.

`service-documentation` *service* [Procedure]
: Return the documentation (a string) of *service*.

4.2 Service Registry

At run time, `shepherd` maintains a *service registry* that maps service names to service records. Service dependencies are expressed as a list of names passed as `#:requirement` to the `service` procedure (see Section 4.1 [Defining Services], page 8); these names are looked up in the registry. Likewise, when running `herd start sshd` or similar commands (see Chapter 2 [Jump Start], page 2), the service name is looked up in the registry.

Consequently, every service must be appear in the registry before it can be used. A typical configuration file thus includes a call to the `register-services` procedure (see Section 4.7 [Service Examples], page 20). The following procedures let you interact with the registry.

`register-services` *services* [Procedure]
: Register *services* so that they can be looked up by name, for instance when resolving dependencies.

  Each name uniquely identifies one service. If a service with a given name has already been registered, arrange to have it replaced when it is next stopped. If it is currently stopped, replace it immediately.

`unregister-services` *services* [Procedure]
: Remove all of *services* from the registry, stopping them if they are not already stopped.

`lookup-service` *name* [Procedure]
: Return the service that provides *name*, `#f` if there is none.

`for-each-service` *proc* [Procedure]
: Call *proc*, a procedure taking one argument, once for each registered service.

`lookup-running` *name* [Procedure]
: Return the running service that provides *name*, or false if none.

4.3 Interacting with Services

What we have seen so far is the interface to *define* a service and to access it (see Section 4.1 [Defining Services], page 8). The procedures below, also exported by the `(shepherd service)` module, let you modify and access the state of a service. You may use them in your configuration file, for instance to start some or all of the services you defined (see Section 4.7 [Service Examples], page 20).

Under the hood, each service record has an associated *fiber* (really: an actor) that encapsulates its state and serves user requests—a fiber is a lightweight execution thread (see Section 7.3 [Service Internals], page 29).

The procedures below let you change the state of a service.

`start-service` *service* `.` *args* [Procedure]
: Start *service* and its dependencies, passing *args* to its `start` method. Return its running value, `#f` on failure.

`stop-service` *service* `.` *args* [Procedure]
: Stop *service* and any service that depends on it. Return the list of services that have been stopped (including transitive dependent services).

  If *service* is not running, print a warning and return its canonical name in a list.

`perform-service-action` *service the-action . args* [Procedure]
Perform *the-action* (a symbol such as `'restart` or `'status`) on *service*, passing it *args*. The meaning of *args* depends on the action.

The `start-in-the-background` procedure, described below, is provided for your convenience: it makes it easy to start a set of services right from your configuration file, while letting `shepherd` run in the background.

`start-in-the-background` *services* [Procedure]
Start the services named by *services*, a list of symbols, in the background. In other words, this procedure returns immediately without waiting until all of *services* have been started.

This procedure can be useful in a configuration file because it lets you interact right away with shepherd using the `herd` command.

The following procedures let you query the current state of a service.

`service-running?` *service* [Procedure]
`service-stopped?` *service* [Procedure]
`service-enabled?` *service* [Procedure]
Return true if *service* is currently running/stopped/enabled, false otherwise.

`service-status` *service* [Procedure]
Return the status of *service* as a symbol, one of: `'stopped`, `'starting`, `'running`, or `'stopping`.

`service-running-value` *service* [Procedure]
Return the current "running value" of *service*—a Scheme value associated with it. It is `#f` when the service is stopped; otherwise, it is a truth value, such as an integer denoting a PID (see Section 4.4 [Service De- and Constructors], page 14).

`service-status-changes` *service* [Procedure]
Return the list of symbol/timestamp pairs representing recent state changes for *service*.

`service-startup-failures` *service* [Procedure]
`service-respawn-times` *service* [Procedure]
Return the list of startup failure times or respawn times of *service*.

`service-replacement` *service* [Procedure]
Return the *replacement* of *service*, or `#f` if there is none.

The replacement is the service that will replace *service* when it is eventually stopped.

See Section 7.3 [Service Internals], page 29, if you're curious about the nitty-gritty details!

4.4 Service De- and Constructors

Each service has a `start` procedure and a `stop` procedure, also referred to as its *constructor* and *destructor* (see Chapter 4 [Services], page 8). The procedures listed below return procedures that may be used as service constructors and destructors. They are flexible enough to cover most use cases and carefully written to complete in a timely fashion.

`make-forkexec-constructor` *command* [*#:user #f*] [*#:group #f*] [*#:supplementary-groups '()*] [*#:pid-file #f*] [*#:pid-file-timeout (default-pid-file-timeout)*] [*#:log-file #f*] [*#:directory (default-service-directory)*] [*#:file-creation-mask #f*] [*#:create-session? #t*] [*#:resource-limits '()*] [*#:environment-variables (default-environment-variables)*] [Procedure]

Return a procedure that forks a child process, closes all file descriptors except the standard output and standard error descriptors, sets the current directory to *directory*, sets the umask to *file-creation-mask* unless it is `#f`, changes the environment to *environment-variables* (using the `environ` procedure), sets the current user to *user* the current group to *group* unless they are `#f` and supplementary groups to *supplementary-groups* unless they are `'()`, and executes *command* (a list of strings.) When *create-session?* is true, the child process creates a new session with `setsid` and becomes its leader. The result of the procedure will be the PID of the child process.

> **Note:** This will not work as expected if the process "daemonizes" (forks); in that case, you will need to pass `#:pid-file`, as explained below.

When *pid-file* is true, it must be the name of a PID file associated with the process being launched; the return value is the PID once that file has been created. If *pid-file* does not show up in less than *pid-file-timeout* seconds, the service is considered as failing to start.

When *log-file* is true, it names the file to which the service's standard output and standard error are redirected. *log-file* is created if it does not exist, otherwise it is appended to.

Guile's `setrlimit` procedure is applied on the entries in *resource-limits*. For example, a valid value would be:

```
'((nproc 10 100)         ;number of processes
  (nofile 4096 4096))    ;number of open file descriptors
```

`make-kill-destructor` [*signal*] [*#:grace-period (default-process-termination-grace-period)*] [Procedure]

Return a procedure that sends *signal* to the process group of the PID given as argument, where *signal* defaults to `SIGTERM`. If the process is still running after *grace-period* seconds, send it `SIGKILL`. The procedure returns once the process has terminated.

This *does* work together with respawning services, because in that case the `stop` method of the `<service>` arranges so that the service is not respawned.

The `make-forkexec-constructor` procedure builds upon the following procedures.

`exec-command` *command* [*#:user #f*] [*#:group #f*] [Procedure]
[*#:supplementary-groups '()*] [*#:log-file #f*] [*#:log-port #f*]
[*#:input-port #f*] [*#:directory* (*default-service-directory*)]
[*#:file-creation-mask #f*] [*#:create-session? #t*] [*#:resource-limits '()*]
[*#:environment-variables* (*default-environment-variables*)]

`fork+exec-command` *command* [*#:user #f*] [*#:group #f*] [Procedure]
[*#:supplementary-groups '()*] [*#:log-file #f*] [*#:log-encoding "UTF-8"*]
[*#:directory* (*default-service-directory*)] [*#:file-creation-mask #f*]
[*#:create-session? #t*] [*#:resource-limits '()*] [*#:environment-variables*
(*default-environment-variables*)]

Run *command* as the current process from *directory*, with *file-creation-mask* if it's true, with *rlimits*, and with *environment-variables* (a list of strings like `"PATH=/bin"`.) File descriptors 1 and 2 are kept as is or redirected to either *log-port* or *log-file* if it's true, whereas file descriptor 0 (standard input) points to *input-port* or `/dev/null`; all other file descriptors are closed prior to yielding control to *command*. When *create-session?* is true, call `setsid` first (see Section "Processes" in *GNU Guile Reference Manual*).

By default, *command* is run as the current user. If the *user* keyword argument is present and not false, change to *user* immediately before invoking *command*. *user* may be a string, indicating a user name, or a number, indicating a user ID. Likewise, *command* will be run under the current group, unless the *group* keyword argument is present and not false, and *supplementary-groups* is not `'()`.

`fork+exec-command` does the same as `exec-command`, but in a separate process whose PID it returns.

`default-environment-variables` [Variable]
This parameter (see Section "Parameters" in *GNU Guile Reference Manual*) specifies the default list of environment variables to be defined when the procedures above create a new process.

It must be a list of strings where each string has the format *`name=value`*. It defaults to what `environ` returns when the program starts (see Section "Runtime Environment" in *GNU Guile Reference Manual*).

`default-pid-file-timeout` [Variable]
This parameter (see Section "Parameters" in *GNU Guile Reference Manual*) specifies the default PID file timeout in seconds, when `#:pid-file` is used (see above). It defaults to 5 seconds.

`default-process-termination-grace-period` [Variable]
This parameter (see Section "Parameters" in *GNU Guile Reference Manual*) specifies the "grace period" (in seconds) after which a process that has been sent `SIGTERM` or some other signal to gracefully exit is sent `SIGKILL` for immediate termination. It defaults to 5 seconds.

`default-respawn-delay` [Variable]
This parameter specifies the default value of the `#:respawn-delay` parameter of `service` (see Section 4.1 [Defining Services], page 8). It defaults to `0.1`, meaning a 100ms delay before respawning a service.

`default-respawn-limit` [Variable]

This parameter specifies the default value of the `#:respawn-limit` parameter of `service` (see Section 4.1 [Defining Services], page 8).

As an example, suppose you add this line to your configuration file:

```
(default-respawn-limit '(3 . 10))
```

The effect is that services will be respawned at most 3 times over a period of 10 seconds before being disabled.

One may also define services meant to be started *on demand*. In that case, shepherd listens for incoming connections on behalf of the program that handles them; when it accepts an incoming connection, it starts the program to handle them. The main benefit is that such services do not consume resources until they are actually used, and they do not slow down startup.

These services are implemented following the protocol of the venerable inetd "super server" (see Section "inetd invocation" in *GNU Inetutils*). Many network daemons can be invoked in "inetd mode"; this is the case, for instance, of `sshd`, the secure shell server of the OpenSSH project. The Shepherd lets you define inetd-style services, specifically those in `nowait` mode where the daemon is passed the newly-accepted socket connection while `shepherd` is in charge of listening.

Listening endpoints for such services are described as records built using the `endpoint` procedure:

`endpoint` *address* [*#:name* "*unknown*"] [*#:style SOCK_STREAM*] [*#:backlog 128*] [*#:socket-owner* (*getuid*)] [*#:socket-group* (*getgid*)] [*#:socket-directory-permissions #o755*] [*#:bind-attempts* (*default-bind-attempts*)] [Procedure]

Return a new endpoint called *name* of *address*, an address as return by `make-socket-address`, with the given *style* and *backlog*.

When *address* is of type `AF_INET6`, the endpoint is *IPv6-only*. Thus, if you want a service available both on IPv4 and IPv6, you need two endpoints. For example, below is a list of endpoints to listen on port 4444 on all the network interfaces, both in IPv4 and IPv6 ("0.0.0.0" for IPv4 and "::0" for IPv6):

```
(list (endpoint (make-socket-address AF_INET INADDR_ANY 4444))
      (endpoint (make-socket-address AF_INET6 IN6ADDR_ANY 4444)))
```

This is the list you would pass to `make-inetd-constructor` or `make-systemd-constructor`—see below.

When *address* is of type `AF_UNIX`, *socket-owner* and *socket-group* are strings or integers that specify its ownership and that of its parent directory; *socket-directory-permissions* specifies the permissions for its parent directory.

Upon '`EADDRINUSE`' ("Address already in use"), up to *bind-attempts* attempts will be made to `bind` on *address*, one every second.

`default-bind-attempts` [Variable]

This parameter specifies the number of times, by default, that `shepherd` will try to bind an endpoint address if it happens to be already in use.

The inetd service constructor takes a command and a list of such endpoints:

`make-inetd-constructor` *command endpoints* [Procedure]
[*#:service-name-stem* _] [*#:requirements* '()] [*#:max-connections* (*default-inetd-max-connections*)] [*#:user #f*] [*#:group #f*] [*#:supplementary-groups* '()] [*#:directory* (*default-service-directory*)] [*#:file-creation-mask #f*] [*#:create-session? #t*] [*#:resource-limits* '()] [*#:environment-variables* (*default-environment-variables*)]

Return a procedure that opens sockets listening to *endpoints*, a list of objects as returned by `endpoint`, and accepting connections in the background.

Upon a client connection, a transient service running *command* is spawned. Only up to *max-connections* simultaneous connections are accepted; when that threshold is reached, new connections are immediately closed.

The remaining arguments are as for `make-forkexec-constructor`.

`make-inetd-destructor` [Procedure]
Return a procedure that terminates an inetd service.

The last type is *systemd-style services*. Like inetd-style services, those are started on demand when an incoming connection arrives, but using the protocol devised by the systemd service manager and referred to as *socket activation* (`https://www.freedesktop.org/software/systemd/man/daemon.html#Socket-Based%20Activation`). The main difference with inetd-style services is that shepherd hands over the listening socket(s) to the daemon; the daemon is then responsible for accepting incoming connections. A handful of environment variables are set in the daemon's execution environment (see below), which usually checks them using the libsystemd or libelogind client library helper functions (`https://www.freedesktop.org/software/systemd/man/sd_listen_fds.html`). The constructor and destructor for systemd-style daemons are described below.

`make-systemd-constructor` *command endpoints* [*#:lazy-start? #t*] [Procedure]
[*#:user #f*] [*#:group #f*] [*#:supplementary-groups* '()] [*#:log-file #f*] [*#:directory* (*default-service-directory*)] [*#:file-creation-mask #f*] [*#:create-session? #t*] [*#:resource-limits* '()] [*#:environment-variables* (*default-environment-variables*)]

Return a procedure that starts *command*, a program and list of argument, as a systemd-style service listening on *endpoints*, a list of `<endpoint>` objects.

command is started on demand on the first connection attempt on one of *endpoints* when *lazy-start?* is true; otherwise it is started as soon as possible. It is passed the listening sockets for *endpoints* in file descriptors 3 and above; as such, it is equivalent to an `Accept=no` systemd socket unit (`https://www.freedesktop.org/software/systemd/man/systemd.socket.html`). The following environment variables are set in its environment:

`LISTEN_PID`
It is set to the PID of the newly spawned process.

`LISTEN_FDS`
It contains the number of sockets available starting from file descriptor 3—i.e., the length of *endpoints*.

`LISTEN_FDNAMES`
: The colon-separated list of endpoint names.

This must be paired with `make-systemd-destructor`.

`make-systemd-destructor` [Procedure]
: Return a procedure that terminates a systemd-style service as created by `make-systemd-constructor`.

The following constructor/destructor pair is also available for your convenience, but we recommend using `make-forkexec-constructor` and `make-kill-destructor` instead (this is typically more robust than going through the shell):

`make-system-constructor` *`command...`* [Procedure]
: The returned procedure will execute *command* in a shell and return `#t` if execution was successful, otherwise `#f`. For convenience, it takes multiple arguments which will be concatenated first.

`make-system-destructor` *`command...`* [Procedure]
: Similar to `make-system-constructor`, but returns `#f` if execution of the *command* was successful, `#t` if not.

4.5 The `root` Service

The service `root` is special, because it is used to control the Shepherd itself. It has an alias `shepherd`. It provides the following actions (in addition to `enable`, `disable` and `restart` which do not make sense here).

`status` Displays which services are started and which ones are not.

`detailed-status`
: Displays detailed information about every registered service.

`load` *`file`* Evaluate in the `shepherd` process the Scheme code in *file*, in a fresh module that uses the `(shepherd services)` module—as with the `--config` option of `shepherd` (see Section 3.1 [Invoking shepherd], page 5).

`eval` *`exp`* Likewise, evaluate Scheme expression *exp* in a fresh module with all the necessary bindings. Here is a couple of examples:

```
# herd eval root "(+ 2 2)"
4
# herd eval root "(getpid)"
1
# herd eval root "(lookup-running 'xorg-server)"
(service (version 0) (provides (xorg-server)) ...)
```

`unload` *`service-name`*
: Attempt to remove the service identified by *service-name*. `shepherd` will first stop the service, if necessary, and then remove it from the list of registered services. Any services depending upon *service-name* will be stopped as part of this process.

If *service-name* simply does not exist, output a warning and do nothing. If it exists, but is provided by several services, output a warning and do nothing. This latter case might occur for instance with the fictional service `web-server`, which might be provided by both `apache` and `nginx`. If *service-name* is the special string and `all`, attempt to remove all services except for the Shepherd itself.

`reload` *file-name*
: Unload all known optional services using unload's `all` option, then load *file-name* using `load` functionality. If file-name does not exist or `load` encounters an error, you may end up with no defined services. As these can be reloaded at a later stage this is not considered a problem. If the `unload` stage fails, `reload` will not attempt to load *file-name*.

`daemonize`
: Fork and go into the background. This should be called before respawnable services are started, as otherwise we would not get the `SIGCHLD` signals when they terminate.

4.6 Legacy GOOPS Interface

From its inception in 2002 with negative version numbers (really!) up to version 0.9.x included, the Shepherd's service interface used GOOPS, Guile's object-oriented programming system (see Section "GOOPS" in *GNU Guile Reference Manual*).

There was a `<service>` class whose instances you could access directly with `slot-ref`; generic functions such as `start` and `stop` had one method accepting a service object and another method accepting the name of a service as a symbol, which it would transparently resolve.

This interface is deprecated. It is still supported in version 0.10.5 but will be removed in the next stable series.

Fortunately, common idioms are easily converted to the current interface. For example, you would previously create a service like so:

```
(make <service>       ;deprecated GOOPS interface
  #:provides '(something)
  #:requires '(another thing)
  #:start ...
  #:stop ...
  #:respawn? #t)
```

With the new interface (see Section 4.1 [Defining Services], page 8), you would write something very similar:

```
(service '(something)
  #:requirement '(another thing)
  #:start ...
  #:stop ...
  #:respawn? #t)
```

Likewise, instead of writing:

```
(start 'whatever)
```

... you would write:

```
(start-service (lookup-service 'whatever))
```

When using one of the deprecated methods, a deprecation warning is emitted, depending on the value of the `GUILE_WARN_DEPRECATED` environment variable (see Section "Environment Variables" in *GNU Guile Reference Manual*).

4.7 Service Examples

The configuration file of the `shepherd` command (see Section 3.1 [Invoking shepherd], page 5) defines, registers, and possibly starts *services*. Each service specifies other services it depends on and how it is started and stopped. The configuration file contains Scheme code that uses the programming interface of the `(shepherd service)` module (see Chapter 4 [Services], page 8).

Let's assume you want to define and register a service to start mcron, the daemon that periodically executes jobs in the background (see Section "Introduction" in *GNU mcron Manual*). That service is started by invoking the `mcron` command, after which `shepherd` should monitor the running process, possibly re-spawning it if it stops unexpectedly. Here's the configuration file for this one service:

```
(define mcron
  (service
    '(mcron)
    ;; Run /usr/bin/mcron without any command-line arguments.
    #:start (make-forkexec-constructor '("/usr/bin/mcron"))
    #:stop (make-kill-destructor)
    #:respawn? #t))

(register-services (list mcron))
```

You can write the snippet above in the default configuration file—`~/.config/shepherd/init.scm` if you run `shepherd` as an unprivileged user. When you launch it, `shepherd` will evaluate that configuration; thus it will define and register the `mcron` service, but it will *not* start it. To start the service, run:

```
herd start mcron
```

Alternatively, if you want `mcron` to be started automatically when `shepherd` starts, you can add this snippet at the end of the configuration file:

```
(start-in-the-background '(mcron))
```

Now let's take another example: `sshd`, the secure shell daemon of the OpenSSH project (`https://www.openssh.com`). We will pass `sshd` the `-D` option so that it does not "detach", making it easy for `shepherd` to monitor its process; we also tell `shepherd` to check its *PID file* to determine once it has started and is ready to accept connections:

```
(define sshd
  (service
    '(sshd ssh-daemon)  ;for convenience, give it two names
    #:start (make-forkexec-constructor
             '("/usr/sbin/sshd" "-D")
             #:pid-file "/etc/ssh/sshd.pid")
```

```
    #:stop (make-kill-destructor)
    #:respawn? #t))

(register-services (list sshd))
(start-in-the-background '(sshd))
```

Alternatively, we can start `sshd` in *inetd mode*: in that case, `shepherd` listens for connection and spawns `sshd` only upon incoming connections. The inetd mode is enabled by passing the `-i` command-line option:

```
(define sshd
  (service
    '(sshd ssh-daemon)
    #:start (make-inetd-constructor
             '("/usr/sbin/sshd" "-D" "-i")
             (list (endpoint
                    (make-socket-address AF_INET INADDR_ANY 22))
                   (endpoint
                    (make-socket-address AF_INET6 IN6ADDR_ANY 22)))
             #:max-connections 10)
    #:stop (make-inetd-destructor)
    #:respawn? #t))

(register-services (list sshd))
(start-in-the-background '(sshd))
```

The `make-socket-address` procedure calls above return the *listening addresses* (see Section "Network Socket Address" in *GNU Guile Reference Manual*). In this case, it specifies that `shepherd` will accept connections coming from any network interface ("0.0.0.0" in IPv4 notation and "::0" for IPv6) on port 22. The `endpoint` calls wrap these addresses in endpoint records (see [endpoints], page 16). When a client connects, `shepherd` accepts it and spawns `sshd -D -i` as a new *transient service*, passing it the client connection. The `#:max-connections` parameter instructs `shepherd` to accept at most 10 simultaneous client connections.

In these examples, we haven't discussed dependencies among services—the `#:requires` keyword of `<service>`—nor did we discuss systemd-style services. These are extensions of what we've seen so far. See Chapter 4 [Services], page 8, for details.

If you use Guix System, you will see that it contains a wealth of Shepherd service definitions. The nice thing is that those give you a *complete view* of what goes into the service—not just how the service is started and stopped, but also what software package is used and what configuration file is provided. See Section "Shepherd Services" in *GNU Guix Reference Manual*, for more info.

4.8 Managing User Services

The Shepherd can be used to manage services for an unprivileged user. First, you may want to ensure it is up and running every time you log in. One way to accomplish that is by adding the following lines to `~/.bash_profile` (see Section "Bash Startup Files" in *The GNU Bash Reference Manual*):

```
if [[ ! -S ${XDG_RUNTIME_DIR-$HOME/.cache}/shepherd/socket ]]; then
    shepherd
fi
```

Then, we suggest the following top-level `$XDG_CONFIG_HOME/shepherd/init.scm` file, which will automatically load individual service definitions from `~/.config/shepherd/init.d`:

```
(use-modules (shepherd service)
             ((ice-9 ftw) #:select (scandir)))

;; Send shepherd into the background
(perform-service-action root-service 'daemonize)

;; Load all the files in the directory 'init.d' with a suffix '.scm'.
(for-each
  (lambda (file)
    (load (string-append "init.d/" file)))
  (scandir (string-append (dirname (current-filename)) "/init.d")
           (lambda (file)
             (string-suffix? ".scm" file))))
```

Then, individual user services can be put in `$XDG_CONFIG_HOME/shepherd/init.d/`, e.g., for `ssh-agent`.

```
;; Add to your ~/.bash_profile:
;;
;; SSH_AUTH_SOCK=${XDG_RUNTIME_DIR-$HOME/.cache}/ssh-agent/socket
;; export SSH_AUTH_SOCK

(use-modules (shepherd support))

(define ssh-agent
  (service
    '(ssh-agent)
    #:documentation "Run `ssh-agent'"
    #:start (lambda ()
              (let ((socket-dir (string-append %user-runtime-dir "/ssh-agent")))
                (unless (file-exists? socket-dir)
                  (mkdir-p socket-dir)
                  (chmod socket-dir #o700))
                (fork+exec-command
                 `("ssh-agent" "-D" "-a" ,(string-append socket-dir "/socket"))
                 #:log-file (string-append %user-log-dir "/ssh-agent.log"))))
    #:stop (make-kill-destructor)
    #:respawn? #t))

(register-services (list ssh-agent))
(start-service ssh-agent)
```

5 Service Collection

The Shepherd comes with a collection of services that let you control it or otherwise extend its functionality. This chapter documents them.

5.1 Monitoring Service

The *monitoring service*, as its name suggests, monitors resource usage of the shepherd daemon. It does so by periodically logging information about key resources: heap size (memory usage), open file descriptors, and so on. It is a simple and useful way to check whether resource usage remains under control.

To use it, a simple configuration file that uses this service and nothing else would look like this:

```
(use-modules (shepherd service monitoring))

(register-services
  ;; Create a monitoring service that logs every 15 minutes.
  (list (monitoring-service #:period (* 15 60))))

;; Start it!
(start-service (lookup-service 'monitoring))
```

Using the `herd` command, you can get immediate resource usage logging:

```
$ herd log monitoring
service names: 3; heap: 8.77 MiB; file descriptors: 20
```

You can also change the logging period; for instance, here is how you'd change it to 30 minutes:

```
$ herd period monitoring 30
```

The `(shepherd service monitoring)` module exports the following bindings:

`monitoring-service` [*#:period* (*default-monitoring-period*)] [Procedure]
: Return a service that will monitor shepherd resource usage by printing it every *period* seconds.

`default-monitoring-period` [Variable]
: This parameter specifies the default monitoring period, in seconds.

5.2 Read-Eval-Print Loop Service

Scheme wouldn't be Scheme without support for *live hacking*, and your favorite service manager had to support it too! The *REPL service* provides a read-eval-print loop (REPL) that lets you interact with it from the comfort of the Guile REPL (see Section "Running Guile Interactively" in *GNU Guile Reference Manual*).

The service listens for connections on a Unix-domain socket—by default `/var/run/shepherd/repl` when running as root and `/run/user/`*uid*`/shepherd/repl` otherwise—and spawns a new service for each client connection. Clients can use the REPL as they would do with a "normal" REPL, except that it lets them inspect and modify the state of the `shepherd` process itself.

Caveat: The live REPL is a powerful tool in support of live hacking and debugging, but it's also a dangerous one: depending on the code you execute, you could lock the `shepherd` process, make it crash, or who knows what.

One particular aspect to keep in mind is that `shepherd` currently uses Fibers in such a way that scheduling among fibers is cooperative and non-preemptive. Beware!

A configuration file that enables the REPL service looks like this:

```
(use-modules (shepherd service repl))

(register-services (list (repl-service)))
```

With that in place, you can later start the REPL:

```
herd start repl
```

From there you can connect to the REPL socket. If you use Emacs, you might fancy doing it with Geiser's `geiser-connect-local` function (see *Geiser User Manual*).

The `(shepherd service repl)` module exports the following bindings.

`repl-service` [*socket-file*] [Procedure]
Return a REPL service that listens to *socket-file*.

`default-repl-socket-file` [Variable]
This parameter specifies the socket file name `repl-service` uses by default.

6 Misc Facilities

This is a list of facilities which are available to code running inside of the Shepherd and is considered generally useful, but is not directly related to one of the other topic covered in this manual.

6.1 Errors

`assert` *expr* [macro]

If *expr* yields `#f`, display an appropriate error message and throw an `assertion-failed` exception.

`caught-error` *key args* [Procedure]

Tell the Shepherd that a *key* error with *args* has occurred. This is the simplest way to cause caught error result in uniformly formatted warning messages. The current implementation is not very good, though.

`without-system-error` *expr...* [macro]

Evaluates the *expr*s, not going further if a system error occurs, but also doing nothing about it.

6.2 Communication

The `(shepherd comm)` module provides primitives that allow clients such as `herd` to connect to `shepherd` and send it commands to control or change its behavior (see Section 4.1 [Defining Services], page 8).

Currently, clients may only send *commands*, represented by the `<shepherd-command>` type. Each command specifies a service it applies to, an action name, a list of strings to be used as arguments, and a working directory. Commands are instantiated with `shepherd-command`:

`shepherd-command` *action service* [*#:arguments '()*] [Procedure]
[*#:directory* (*getcwd*)]

Return a new command (a `<shepherd-command>`) object for *action* on *service*.

Commands may then be written to or read from a communication channel with the following procedures:

`write-command` *command port* [Procedure]

Write *command* to *port*.

`read-command` *port* [Procedure]

Receive a command from *port* and return it.

In practice, communication with `shepherd` takes place over a Unix-domain socket, as discussed earlier (see Section 3.1 [Invoking shepherd], page 5). Clients may open a connection with the procedure below.

`open-connection` [*file*] [Procedure]
: Open a connection to the daemon, using the Unix-domain socket at *file*, and return the socket.

  When *file* is omitted, the default socket is used.

The daemon writes output to be logged or passed to the currently-connected client using `local-output`:

`local-output` *format-string . args* [Procedure]
: This procedure should be used for all output operations in the Shepherd. It outputs the *args* according to the *format-string*, then inserts a newline. It writes to whatever is the main output target of the Shepherd, which might be multiple at the same time in future versions.

Under the hood, `write-command` and `read-command` write/read commands as s-expressions (sexps). Each sexp is intelligible and specifies a protocol version. The idea is that users can write their own clients rather than having to invoke `herd`. For instance, when you type `herd status`, what is sent over the wire is the following sexp:

```
(shepherd-command
  (version 0)
  (action status) (service root)
  (arguments ()) (directory "/data/src/dmd"))
```

The reply is also an sexp, along these lines:

```
(reply (version 0)
       (result (((service ...) ...)))
       (error #f) (messages ()))
```

This reply indicates that the `status` action was successful, because `error` is `#f`, and gives a list of sexps denoting the status of services as its `result`. The `messages` field is a possibly-empty list of strings meant to be displayed as is to the user.

7 Internals

This chapter contains information about the design and the implementation details of the Shepherd for people who want to hack it.

The GNU Shepherd is developed by a group of people in connection with Guix System (`https://www.gnu.org/software/guix/`), GNU's advanced distribution, but it can be used on other distros as well. You're very much welcome to join us! You can report bugs to `bug-guix@gnu.org` and send patches or suggestions to `guix-devel@gnu.org`.

7.1 Coding Standards

About formatting: Use common sense and GNU Emacs (which actually is the same, of course), and you almost can't get the formatting wrong. Formatting should be as in Guile and Guix, basically. See Section "Coding Style" in *GNU Guix Reference Manual*, for more info.

7.2 Design Decisions

> **Note:** This section was written by Wolfgang Jährling back in 2003 and documents the original design of what was then known as GNU dmd. The main ideas remain valid but some implementation details and goals have changed.

The general idea of a service manager that uses dependencies, similar to those of a Makefile, came from the developers of the GNU Hurd, but as few people are satisfied with System V Init, many other people had the same idea independently. Nevertheless, the Shepherd was written with the goal of becoming a replacement for System V Init on GNU/Hurd, which was one of the reasons for choosing the extension language of the GNU project, Guile, for implementation (another reason being that it makes it just so much easier).

The runlevel concept (i.e. thinking in *groups* of services) is sometimes useful, but often one also wants to operate on single services. System V Init makes this hard: While you can start and stop a service, `init` will not know about it, and use the runlevel configuration as its source of information, opening the door for inconsistencies (which fortunately are not a practical problem usually). In the Shepherd, this was avoided by having a central entity that is responsible for starting and stopping the services, which therefore knows which services are actually started (if not completely improperly used, but that is a requirement which is impossible to avoid anyway). While runlevels are not implemented yet, it is clear that they will sit on top of the service concept, i.e. runlevels will merely be an optional extension that the service concept does not rely on. This also makes changes in the runlevel design easier when it may become necessary.

The consequence of having a daemon running that controls the services is that we need another program as user interface which communicates with the daemon. Fortunately, this makes the commands necessary for controlling services pretty short and intuitive, and gives the additional bonus of adding some more flexibility. For example, it is easiely possible to grant password-protected control over certain services to unprivileged users, if desired.

An essential aspect of the design of the Shepherd (which was already mentioned above) is that it should always know exactly what is happening, i.e. which services are started and

stopped. The alternative would have been to not use a daemon, but to save the state on the file system, again opening the door for inconsistencies of all sorts. Also, we would have to use a separate program for respawning a service (which just starts the services, waits until it terminates and then starts it again). Killing the program that does the respawning (but not the service that is supposed to be respawned) would cause horrible confusion. My understanding of "The Right Thing" is that this conceptionally limited strategy is exactly what we do not want.

The way dependencies work in the Shepherd took a while to mature, as it was not easy to figure out what is appropriate. I decided to not make it too sophisticated by trying to guess what the user might want just to theoretically fulfill the request we are processing. If something goes wrong, it is usually better to tell the user about the problem and let her fix it, taking care to make finding solutions or workarounds for problems (like a misconfigured service) easy. This way, the user is in control of what happens and we can keep the implementation simple. To make a long story short, *we don't try to be too clever*, which is usually a good idea in developing software.

If you wonder why I was giving a "misconfigured service" as an example above, consider the following situation, which actually is a wonderful example for what was said in the previous paragraph: Service X depends on symbol S, which is provided by both A and B. A depends on AA, B depends on BB. AA and BB conflict with each other. The configuration of A contains an error, which will prevent it from starting; no service is running, but we want to start X now. In resolving its dependencies, we first try to start A, which will cause AA to be started. After this is done, the attempt of starting A fails, so we go on to B, but its dependency BB will fail to start because it conflicts with the running service AA. So we fail to provide S, thus X cannot be started. There are several possibilities to deal with this:

- When starting A fails, terminate those services which have been started in order to fulfill its dependencies (directly and indirectly). In case AA was running already, we would not want to terminate it. Well, maybe we would, to avoid the conflict with BB. But even if we would find out somehow that we need to terminate AA to eventually start X, is the user aware of this and wants this to happen (assuming AA was running already)? Probably not, she very likely has assumed that starting A succeeds and thus terminating AA is not necessary. Remember, unrelated (running) services might depend in AA. Even if we ignore this issue, this strategy is not only complicated, but also far from being perfect: Let's assume starting A succeeds, but X also depends on a service Z, which requires BB. In that case, we would need to detect in the first place that we should not even try to start A, but directly satisfy X's dependency on S with B.
- We could do it like stated above, but stop AA only if we know we won't need it anymore (for resolving further dependencies), and start it only when it does not conflict with anything that needs to get started. But should we stop it if it conflicts with something that *might* get started? (We do not always know for sure what we will start, as starting a service might fail and we want to fall back to a service that also provides the particular required symbol in that case.) I think that either decision will be bad in one case or another, even if this solution is already horribly complicated.
- When we are at it, we could just calculate a desired end-position, and try to get there by starting (and stopping!) services, recalculating what needs to be done whenever starting a service fails, also marking that particular service as unstartable, except if it

fails to start because a dependency could not be resolved (or maybe even then?). This is even more complicated. Instead of implementing this and thereby producing code that (a) nobody understands, (b) certainly has a lot of bugs, (c) will be unmaintainable and (d) causes users to panic because they won't understand what will happen, I decided to do the following instead:

- Just report the error, and let the user fix it (in this case, fix the configuration of A) or work around it (in this case, disable A so that we won't start AA but directly go on to starting B).

I hope you can agree that the latter solution after all is the best one, because we can be sure to not do something that the user does not want us to do. Software should not run amok. This explanation was very long, but I think it was necessary to justify why the Shepherd uses a very primitive algorithm to resolve dependencies, despite the fact that it could theoretically be a bit more clever in certain situations.

One might argue that it is possible to ask the user if the planned actions are ok with her, and if the plan changes ask again, but especially given that services are supposed to usually work, I see few reasons to make the source code of the Shepherd more complicated than necessary. If you volunteer to write *and* maintain a more clever strategy (and volunteer to explain it to everyone who wants to understand it), you are welcome to do so, of course. . .

7.3 Service Internals

Under the hood, each service record has an associated *fiber*, a lightweight execution thread (see Section "Introduction" in *Fibers*). This fiber encapsulates all the *state* of its corresponding service: its status (whether it's running, stopped, etc.), its "running value" (such as the PID of its associated process), the time at which its status changed, and so on. Procedures that access the state of a service, such as `service-status`, or that modify it, such as `start-service` (see Section 4.3 [Interacting with Services], page 12), merely send a message to the service's associated fiber.

This pattern follows the *actor model*: each of these per-service fibers is an *actor*. There are several benefits:

- each actor has a linear control flow that is easy to reason about;
- access and modification of the service state are race-free since they are all handled sequentially by its actor;
- the actor's code is purely functional, which again makes it easier to reason about it.

There are other actors in the code, such as the service registry (see Section 4.2 [Service Registry], page 12). Fibers are used pervasively throughout the code to achieve concurrency.

Note that Fibers is set up such that the `shepherd` process has only one POSIX thread (this is mandated by POSIX for processes that call `fork`, with all its warts), and fibers are scheduled in a cooperative fashion. This means that it is possible to block the `shepherd` process for instance by running a long computation or by waiting on a socket that is not marked as `SOCK_NONBLOCK`. Be careful!

We think this programming model makes the code base not only more robust, but also very fun to work with—we hope you'll enjoy it too!

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